Revisiting the effects of the Ethiopian land tenure reform using satellite data

A focus on climate change mitigation and adaptation

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Background

- Land registration and certification (LRCP) programme introduced in 1998
  - Objectives: increase tenure security, hence incentives to undertake long-term land related investments (Deininger and Jin, 2006; Deininger et al., 2008).
  - Implemented first in Tigray in 1998. Reportedly, 88% coverage by 1998
- Several studies have assessed the effects of the Tigray LRCP on:
  - Tenure security (Holden et al. 2011a, 2011b and 2009;)
  - Investment (Holden 2009, Mekonnen et al. (2013), Holden and Ghebru (2015))
  - Welfare effects (IFPRI (2013); Ghebru and Holden (2013))

Why another paper?

- Missing link: climate change mitigation and adaptation.
  - Climate change objectives were not embedded in the original goals of land reformers
  - ... yet, tenure security has been linked to climate-smart agriculture (investment) which brings benefits in terms both adaptation and mitigation
    - *Assurance effect*
    - *Gains from trade*
  - Remote sensing data (9×9 km pixels) for the period 1991–2004
    - Increased geographic coverage

Remote sensing data

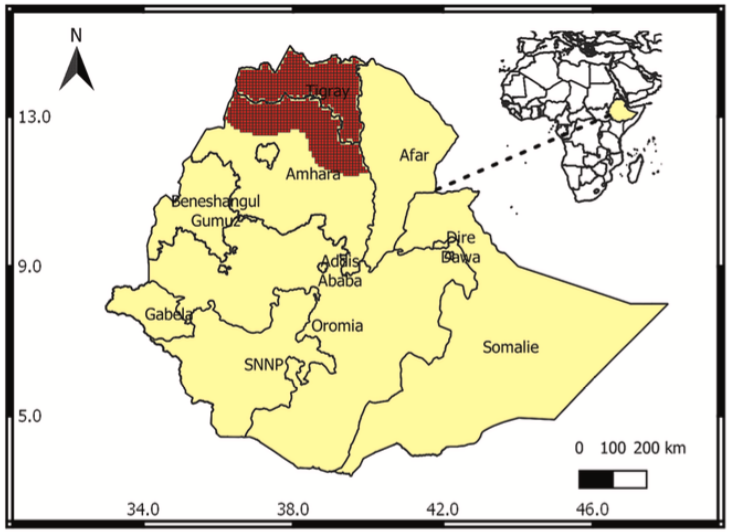
- Tigray and Northern Amhara: similar agro-ecological characteristics, excludes pilot in 2003.

- Normalised Difference Vegetation Index (NDVI) - *Greenness* (NOAA) for 1,008 pixels

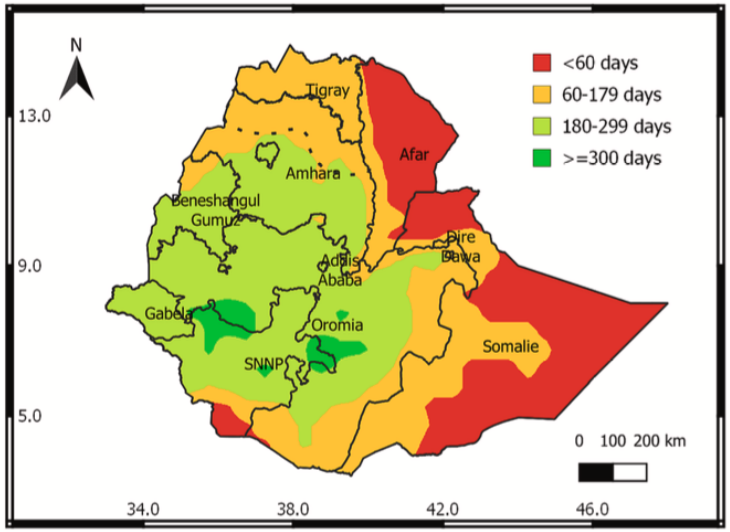
- Monthly observations (for the period 1991 to 2004: 169,344 observations

- Precipitation (CHIRPS) , temperature (FLDAS) and wind speed (TerraClimate)

- Palmer Drought Severity Index (PDSI) to identify dry spells but also abnormal wet periods.



a) Study area (pixels in red)



c) Length of growing period

NDVI, agricultural productivity and carbon storage

- Various studies have used NDVI as a measure of agricultural productivity. And some have explicitly investigated their association, also in the context of Ethiopia. (Groten, 1993; Lewis et al., 1998; Mkhabela et al., 2005); Meshesha and Abeje, 2018; Asher and Novosad (2020); Gazeaud and Stephane (2022)
- Also considered a measure of carbon capture and net primary productivity. Tucker et al. (1986) (GEF, 2016; Sha et al., 2022; Sims et al., 2021; Vlek et al., 2010; Yengoh et al., 2015)

	Grains yields	Temporary crops yields	NPP (WaPOR, 2009-2013)	NPP (MODIS, 2001-2013)
	(1)	(2)	(3)	(4)
NDVI	2.375***	2.326***	5.341***	4.516***
	(0.460)	(0.478)	(0.137)	(0.213)
			Yes	Yes
			Yes	Yes
Region FE	Yes	Yes	Yes	Yes
Observations	63	63	60,480	157,248

Difference in differences approach

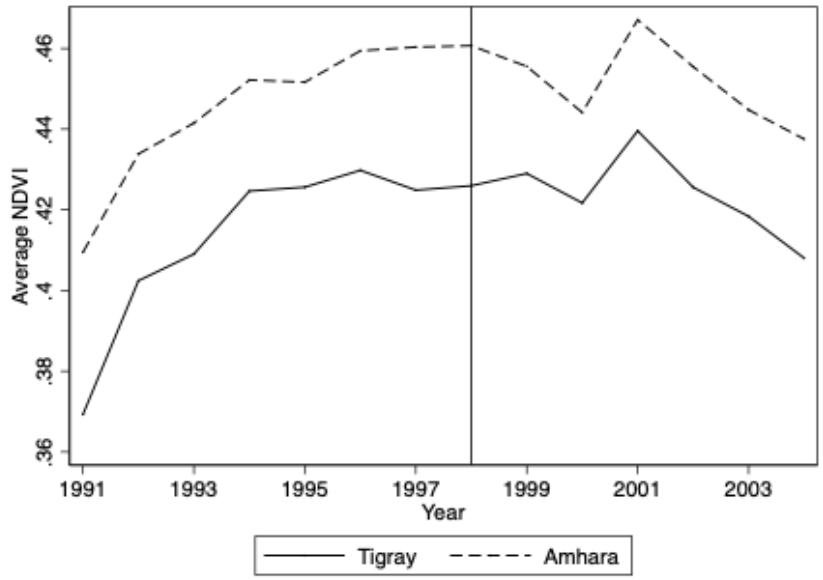
To investigate whether the LRCP contributed to increases in agricultural productivity and to climate change mitigation:

$$NDVI_{irt} = \beta_1(T)_{ir} \times \text{Post}_t + \mu_i + \eta_t + \epsilon_{irt}$$

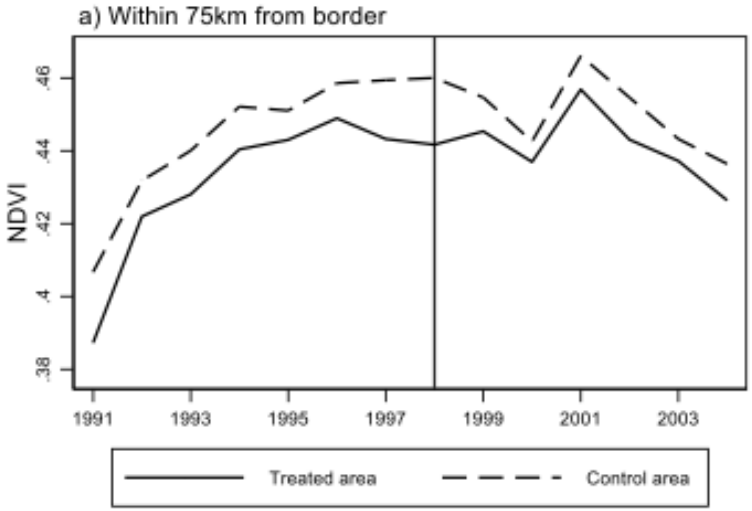
To investigate the effects on climate change adaptation, we restrict our dataset to include only years, where adverse climate and weather events, i.e. Palmer Drought Severity Index below - 1 ("mild drought" conditions or worse).

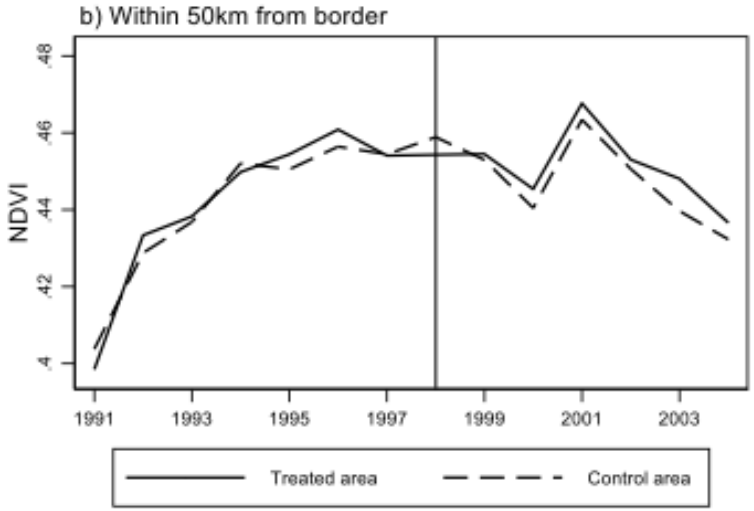
Descriptive evidence

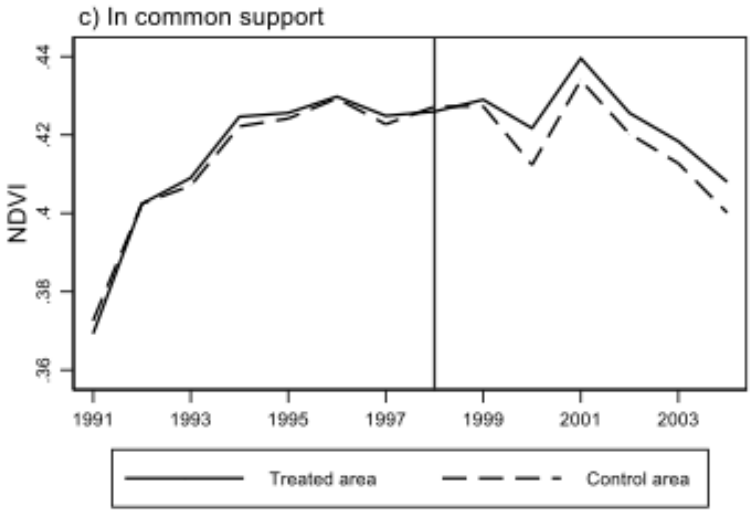
Figure: Average NDVI by region, over time

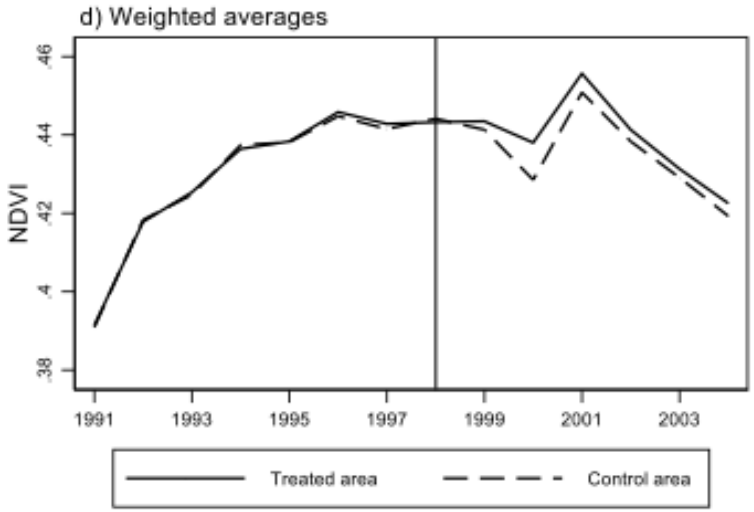


Identification: differences in levels



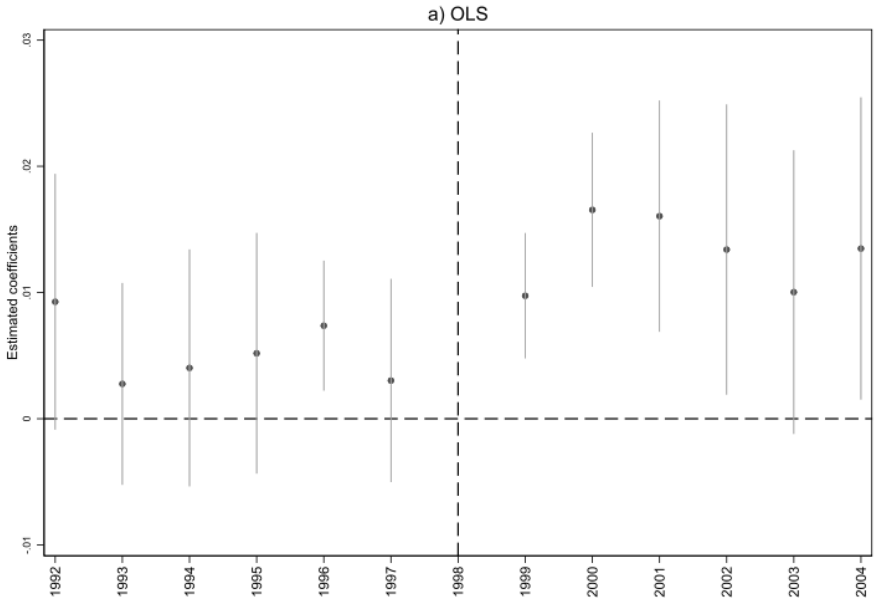


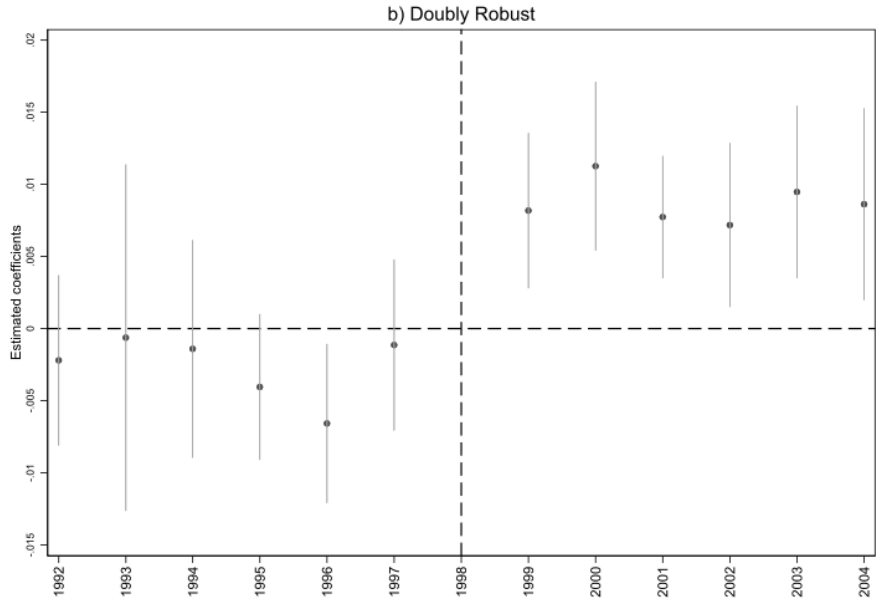




Identification: differences in trends

$$NDVI_{irt} = \sum_{t=-q}^{m} \lambda(T)_{irt} + \theta X_{irt} + \mu_i + \eta_t + \epsilon_{irt}$$





Baseline results

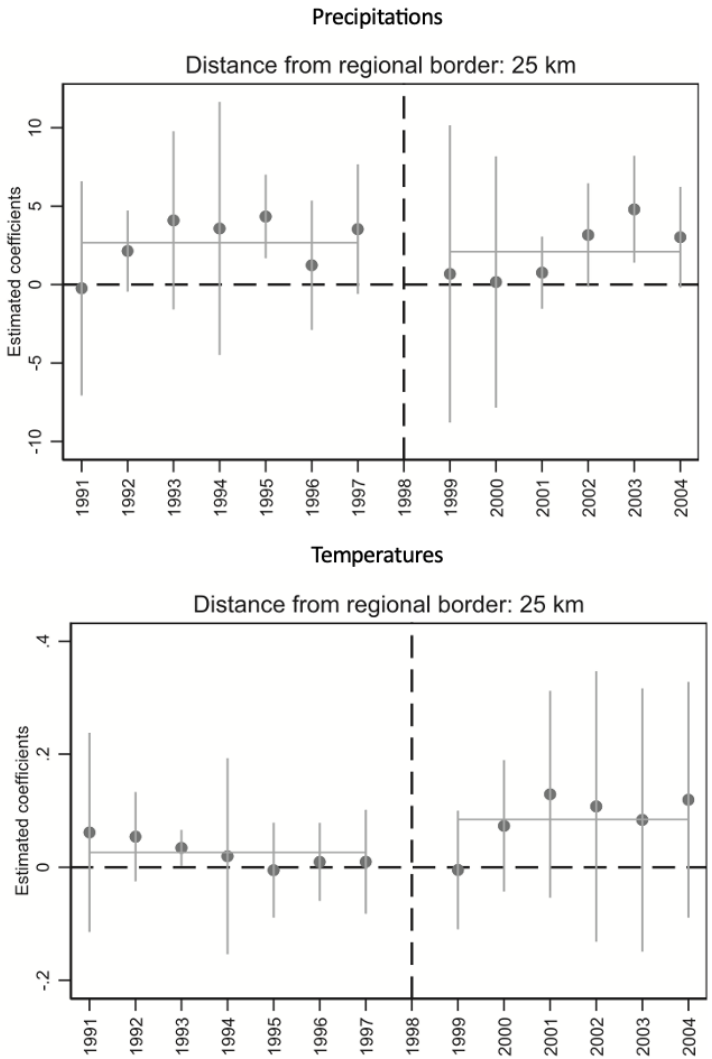
Land productivity and mitigation

Effects are overall small, but relatively large when compared, for example, to projects specifically aimed at promoting land improvements and soil and water conservation measures (e.g. the Productive Safety Net Program in 2005, Gazeaud and Stephane (2022)).

Dependent variable: NDVI	(1) OLS	(2) OLS	(3) Doubly Robust
ATT	0.005***	0.009***	0.009***
	(0.002)	(0.002)	(0.003)
FE	Yes	Yes	Yes
Controls	No	Yes	Yes
NDVI mean (st.dev.)		0.433 (0.137)	
Observations (pixels)		169,344 (1,008)	

Additional robustness checks

- Check for differences in trends in weather conditions
- Woreda time-trends
- Average instead of Maximum NDVI
- Exclusion of westernmost areas of Tigray and Amhara



Baseline results

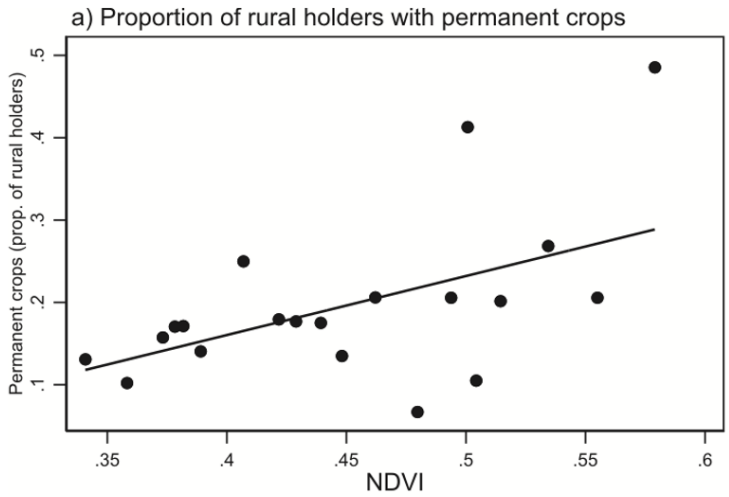
Climate change adaptation

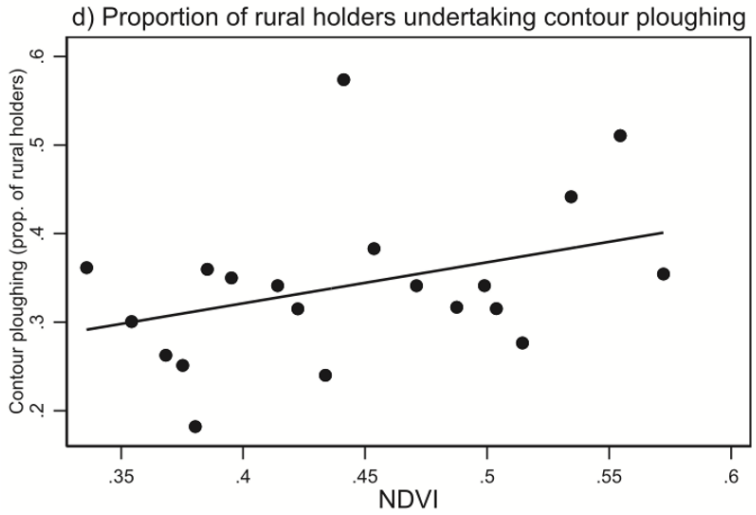
We identified nine years with abnormal rainfall conditions during the growing season, before and after the LRCP

Dependent variable: NDVI	(1) OLS	(2) OLS	(3) Doubly Robust
ATT	0.007***	0.010***	0.009***
	(0.002)	(0.002)	(0.003)
FE	Yes	Yes	Yes
Controls	No	Yes	Yes
NDVI mean (st.dev.)		0.420 (0.133)	
Observations (pixels)		108,864 (1,008)	

Mechanisms

- Tenure security $\rightarrow$ Climate-smart agriculture (CSA) (Ali et al. 2011)
- CSA strategies based on 2001 Census at district level (woreda): permanent crops and contour ploughing
- Strong positive correlation between NDVI and adoption rates
  - Even after controlling for slope, elevation, weather





Conclusions

- The Tigray LRCP had positive effects on NDVI, both when employing our full dataset and when using a sub-dataset of years, where adverse climate and weather events occurred.
  - Productivity, climate change adaptation and climate change mitigation, at a regional scale on measures.
  - Effects are comparable to those produced by programmes targetting land improvements, and linked to CSA practices
- Land reform and tenure securing enabling CSA and in supporting the achievement of rural development objectives, including objectives associated with climate change.
- Remote sensing data useful to complement survey-based evidence